WORKSHOP ON MESOSCOPIC AND NANOSCOPIC SCIENCE USING X-RAY TECHNIQUES

Introduction to Workshop

Eric Isaacs (ANL)

Sunil Sinha (UCSD/LANL)

Workshop Chairs

August 29 – September 1, 2004, The Abbey, Fontana, Lake Geneva Area, WI

Is a part of a study to explore future scientific directions for the Advanced Photon Source (APS)

Chair: Gopal Shenoy (APS/ANL)

Co-Chair: Sunil Sinha (UCSD/LANL)

August 29 – September 1, 2004, The Abbey, Fontana, Lake Geneva Area, WI

Workshops held at the APS

1 **Future Directions in Synchrotron Environmental Science**
(APS Users' Meeting, May 4, 2004, APS)
Chairs: Steve Sutton, Ken Kemner, Shelly Kelly

2 **Emerging Areas in Biological Crystallography**
(Dates July 26-28, 2004, APS)
Chairs: Wayne Hendrickson, John Helliwell

3 **Frontier Science Using Soft X-rays**
(August 5-6, 2004, APS)
Organizers: Richard Rosenberg, Juan Carlos Campuzano

4 **Science with High-Energy X-rays**
(August 9-10, 2004, APS)
Chair: Dean Haeffner

5 **Membrane Science**
(August 17-18, 2004, APS)
Chairs: Millicent Firestone, Tom Irving, Jin Wang, Randall Winans

Workshops at the Abbey in Lake Geneva, WI

6. Emerging Scientific Opportunities with X-ray Imaging
(August 29 to September 1, 2004, Lake Geneva)
Chairs: Francesco De Carlo, Wah Keat Lee,
Gabrielle Long, Stuart Stock

7 Time Domain Science Using X-ray Techniques
(August 29 to September 1, 2004, Lake Geneva)
Chairs: Lin Chen, David Reis, Steve Milton, Linda Young

8. Mesoscopic and Nanoscopic Science Using X-ray Techniques
(August 29 to September 1, 2004, Lake Geneva)
Chairs: Sunil Sinha, Eric Isaacs

9 Nanomagnetism Using X-ray Techniques
(August 29 to September 1, 2004, Lake Geneva)
Chairs: Sam Bader, Laura Lewis, George Srajer

Workshop Scope

- **To understand the fundamental behavior of individual building blocks of mesoscopic and nanoscopic systems, which are combined into more complex structures leading to systems with new functionalities.**

- **Evaluate the advances in mesoscopic and nanoscopic science that are exciting and significan. (What are the key issues/questions?)**

Workshop Scope (contd.)

- **Areas of mesoscopic and nanoscopic materials where x-ray characterization techniques will advance the synthesis**
- **Discuss potential new x-ray methods which will provide insight into mesoscopic and nanoscopic properties and behavior. (How can we use SR to address some of these key issues/questions?)**

Grand Challenges In Understanding Mesoscopic and Nanoscopic Materials Properties and Opportunities for X-ray Techniques to Address them

August 29 – September 1, 2004, The Abbey, Fontana, Lake Geneva Area, WI

Why study Nanoscale Materials?

- **Can create materials not found in nature with new physical, chemical, functional properties.**

Some scientific issues

- **Effects of Confinement or Finite Size**
- **Proximity Effects**
- **Organization Effects (e.g. patterning; self-organization; cooperative phenomena)**

Confinement and Finite Size

- **3D**

  Nanocrystalline Materials; (single-grain, sintered, lower dislocation density)

  Cluster Compounds, Bucky Balls, etc.

  Fluids in Nanoporous Media

  Quantum Dots; Droplets; Deposited Clusters

  Single Macromolecules

Confinement and Finite Size

- **2D**

  Thin Films; Fluids confined in Channels; Layered Compounds; Multilayers

  Quantum or Magnetic Dot Arrays

  Carbon nanotubes

- **1D**

  Quantum Nanowires

  Fluids, Molecules in Carbon Nanotubes

Interesting Basic Science Questions

- **Phase Transitions when the Correlation Length exceeds the System Size**
- **New Spin and Charge Ground States and Excitation Spectra**
- **New Dynamics for Polarization and Charge Transport**

Potential Applications

- **Novel Electronics**

  "Spintronics“

- **High and Low Dielectric Constant Materials**

- **Molecular Level “Chips” and Quantum Computing**

Potential Applications

- **Information Storage and Retrieval**

  Giant Magnetoresistance, Spin Valves, High Density Magnetic Storage with Long-Term Stability

- **New, High Strength Materials**

Characterization Tools for Nanoscale Materials

- X-ray and Neutron Scattering
- Electron Microscopy
- AFM, STM, MFM, NSOM
- Scanning X-ray Nanoprobe

Characterization Tools for Nanoscale Materials

- X-ray Imaging Techniques
- PEEM and Photoemission Spectroscopy
- Computer Simulations and Theory

Practical Challenges

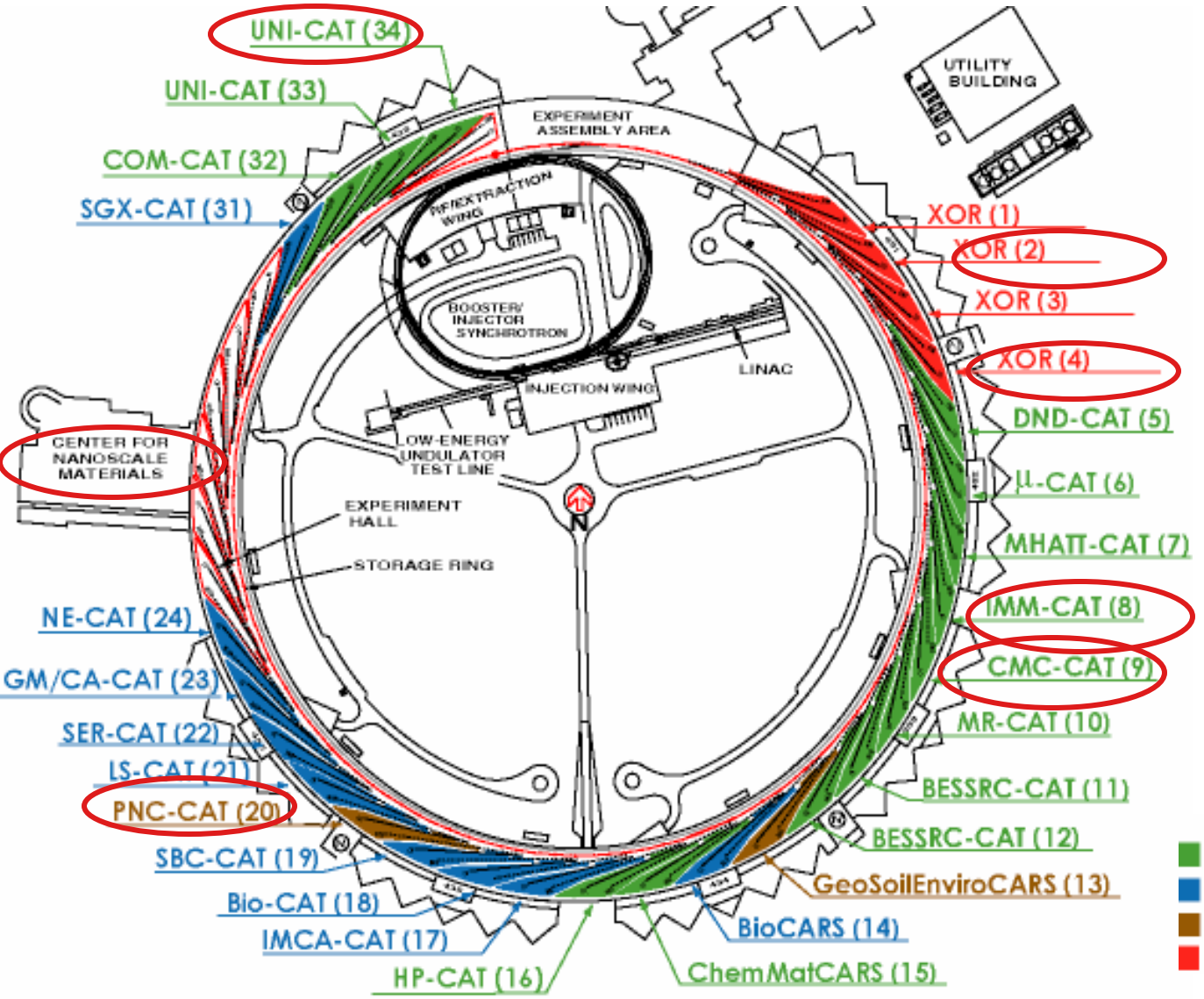
- *Higher beam brilliance with preserved coherence*
  - *Enhancing coherence*
  - *Photon energy ranges of interest*
  - *Nanofocus capabilities*

- *Techniques required to address scientific challenges -?*

- *Unique experimental environments*
  - *In situ measurements during synthesis*
  - *Controlled environments to produce membranes to nanojets*
  - *Integration of laboratory based techniques with x-ray tools (E.g. Optical measurements)*
  - *Need for large magnetic and electric fields*
  - *Angstrom accuracy and reproducibility scanning stages*

- *R&D new x-ray techniques, Etc., Etc……*

APS Nanomagnetism Study Capabilities



- XOR (S 2,4)
- IMM (S 8)
- CMC (S 9)
- PNC (S 20)
- NANO (S 26)
- UNI (S 34)

MATERIALS, CHEMICAL, & ATOMIC SCIENCE
BIOLOGY
GEO, SOIL, & ENVIRONMENTAL SCIENCE
INSTRUMENTATION

Draft Workshop Objectives

1. **Explore the breadth of mesoscopic and nanoscopic science covered by the workshop topics, *not* limiting to synchrotron techniques alone.**

2. **Identify opportunities for continued scientific and technology discoveries using the APS and Center for Nanoscale Materials (CNM) during the next 5-10 years and their potential impact.**

3. **Identify new scientific proposals/programs specific to the emerging areas of meso- and nano-materials that the participants will bring to the APS during next 5 to 10 years. Also evaluate the capital and operational requirements for these proposals /programs.**

Draft Workshop Objectives

4. **In addition to available beamline capabilities at the APS, identify future needs to support research in this area of science and technology.**

5. **Address R&D in enhancing the capabilities of the APS to support the area of meso- and nanoscopic science.**

6. **Address the need and support for theoretical work to strengthen the experimental research.**

7. **Prepare a summary document for the archival literature to serve as a roadmap for the meoscopic and nanoscopic research using x-rays at the APS Source and suggest the role of the Advanced Photon Source towards this objective.**